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# FSD5 Proceedings

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"Multi-functional **farming systems** in a **changing world**"

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# Tailoring cropping systems to variable climate, diverse farms and landscapes

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## 1 Introduction

Soil fertility depletion and climatic volatility are the major biophysical barriers confronting small scale farmers in Africa (e.g. Smaling *et al.*, 1997; Challinor *et al.*, 2007). On the other hand, African farming systems and landscapes are highly heterogeneous creating complex socio-ecological environments characterised by wide differences in farmers' resource endowments and the use of such resources (van Wijk *et al.*, 2009). Although a basket of possible technologies is available, poor resource endowments and seed and fertilizer costs limit the options available for farmers to improve their circumstances. Predictive crop modelling may help to explore the *ex ante* effects of an array of intensification options and answer most of the 'what if' questions (Jones *et al.*, 2003). Participatory modelling with farmers provides for integrative analysis and development of alternatives for increased productivity and sustainability, at both the cropping and farming systems levels. Thus a comprehensive farm design has to take into account climatic variability and change, diverse farms (household priorities and production objectives), and a landscape consisting of fields of different soil fertility status. The objective of this study was to assess the potential of conventional tillage and conservation agriculture to offset the effects of climate variability and change on crop productivity across farms of different resource endowment. This interactive analysis at multi-scales allows the identification of cropping systems that are suitable to farmers' conditions, increase productivity and offer possible adaptation strategies to climate variability and change.

## 2 Materials and Methods

The modelling approach used historical as well as generated future climatic data, farm and field typologies from a case study site in Monze, Zambia to explore the trajectories of current and alternative cropping systems. Climatic data was input into the Agricultural Production Systems Simulator (APSIM), version 7.6 with management scenarios derived from different farm typologies created by classifying farmers based on resource ownership and production orientation. The model was described in detail by Keating *et al.* (2003). APSIM is a process-based model developed to simulate biophysical processes in farming systems in response to management decisions as well as climatic perturbations (Keating *et al.*, 2003). In this study the APSIM model was used to simulate the productivity of maize under conventional and conservation agriculture options with different scenarios of future climate change generated using global circulation models (GCMs). APSIM was calibrated and evaluated using data derived from a long-term agronomic experiment at Monze in Zambia. Future climate change met files were generated by an ensemble of 17 global circulation models (GCMs) using two extreme emission scenarios: (a) the low emission scenario - Representative Concentration Pathway (RCP2.6), and (b) the high emission scenario - Representative Concentration Pathway (RCP8.5). The weather files were generated and downscaled using MarkSim web version for IPCC AR5 data (CMIP5) (Jones & Thornton, 2000). To assess effects of climate change, the 2013/14 cropping season was taken as base and compared with the future season of 2049/50.

## 3 Results - Discussion

Future (2049/50) projected climate for Monze showed no significant change in solar radiation, but higher total season rainfall compared with current climatic conditions. There was an increase in both minimum (+1°C) and maximum (+1.5 °C) temperatures for the two emission scenarios. However, the ensemble of models showed high variability indicating an uncertainty in future climate prediction. Farmer classification revealed four broad farm types (F1-F4) which confirmed the existence of heterogeneity across farms with fertiliser use ranging from 0 kg $ha^{-1}$ to 100 kg $ha^{-1}$ per year. Livestock ownership and land cultivated also differed greatly across the farms (2.5 - 4.3 ha $yr^{-1}$). Consequently these differences had a significant effect on crop productivity (Fig. 1). There was a direct relationship between resource ownership and crop productivity for both climate change scenarios. Farm type two (F2) who did not own cattle and did not afford fertiliser achieved the least yield that contrasted sharply with that from F4 farmers who owned the most livestock and applied the largest fertiliser of about 100 kg $ha^{-1}$. Simulated crop yield results showed that the advantage of CA in the future will be for the low emission scenario only (Fig. 1). This is because of the projected increase in rainfall in combination with the moisture conservation effects through crop residues retention that may lead to waterlogging (Araya and Stroosnijder, 2010).

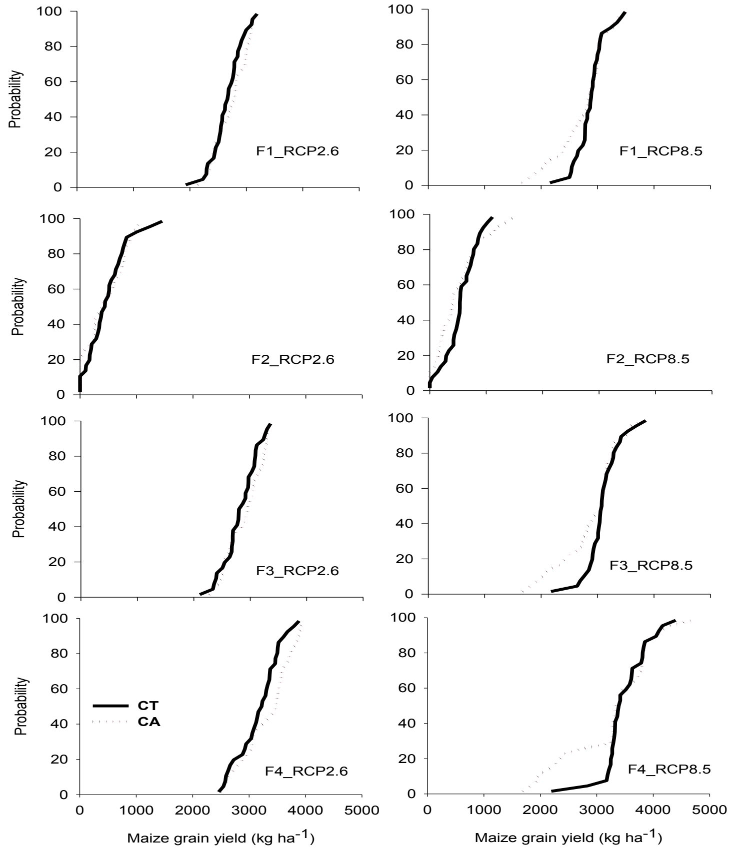


**Fig. 1.** Maize yield probability distribution for conventional tillage (CT) and conservation agriculture (CA) with projected future climate (RCP2.6 and RCP8.5) for the four farm types (F1-F4).

## 4 Conclusions

CA has potential to mitigate against moisture stress but may depress yields when moisture is abundant. There is need to understand better the impact of a combined increase in both temperature and rainfall as the the impact of this two variables has been assessed when temperature is predicted to increase and rainfall to decrease. Historical data shows that cropping seasons are starting late which reduces significantly the planting window i.e. the option of staggering planting dates to deal with climatic uncertainties may not be viable in the future.

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